URS

June 28, 2000

Mr. Walter Payne
Hydrogeologist
Environmental Cleanup Program
Pennsylvania Department of Environmental Protection
Lee Park, Suite 6010
555 North Lane
Conshohocken, PA 19428

Re: Response to Comments
Sunoco, Inc. (R&M) Marcus Hook Refinery – Phillips Island
Land Recycling Program Identification Number 1-23-825-28219
Marcus Hook, Delaware County

Dear Mr. Payne:

Thank you for meeting with URS/Dames & Moore on June 13, 2000 to discuss your technical comments on the Act 2 Combined Report for the referenced site. This correspondence provides responses to the action items from the meeting that were detailed in URS/Dames & Moore's letter of June 15, 2000.

1. Section 6.1, Fate and Transport Analysis

As you suggested, URS/Dames & Moore varied some of the input parameters used in the Quick Domenico model for fate and transport analysis at the site. The key model input parameters that were changed for the supplement calculation and their sources consisted of the following:

Parameters changed for the supplement calculation:

- Hydraulic Gradient: 0.0225 for MW-118, 0.0225 for MW-137, 0.013 for MW-141, 0.41 for MW-143, and 0.0022 for MW-145; well-specific hydraulic gradient calculated from the March 15, 2000 gauging event.
- Porosity: 20%, the default value recommended by PADEP, first version of Technical Guidance Manual
- Soil Bulk Density: 1.8 g/cm3, the average for soil, recommended by PADEP, first version of Technical Guidance Manual
- Fraction Organic Carbon (foc): 0.0025 default recommended by PADEP, first version of Technical Guidance Manual

URS Corporation
2325 Maryland Road, 2nd Floor
Willow Grove, PA 19090
Tel: 215.657.5000
Fax: 215.657.5454

The results obtained by using the Quick Domenico model for benzene, dichloromethane, trichloroethylene, bis(2-ethylhexyl)phthalate, and 4-methylphenol are provided as Attachment 1. In each case changing the input parameters did not appreciably change the distance traveled until the applicable MSC is met (i.e., did not intercept a potentially sensitive receptor such as the Delaware River). The Quick Domenico model estimates:

- The benzene concentration will be less than the applicable MSC 80 feet from MW-118 and less than one foot from MW-141.
- The dichloromethane concentration was estimated to be below the MSC 27 feet from MW-137.
- The trichloroethylene concentration was estimated to be below the MSC 35 feet from MW-145.
- The bis(2-ethylhexyl)phthalate concentration was estimated to be below the MSC 1 foot from MW-145
- The 4-methylphenol concentration will be less than the applicable MSC 2 feet from MW-143

As before, the model projects attenuation of constituents over very short distances from sources. The analysis demonstrates that the controlling factor limiting the transport of contaminants in groundwater at the site is the very low hydraulic conductivity of the fill and native materials at the site.

2. Section 6.2, Surface Water Impact Assessment

The reference sources of the parameters used in the calculation of the surface water impact assessment have been provided below.

Equation 1:

$$C_{sw} = \frac{Q_{gw} \times C_{gw}}{Q_{sw}}$$

Where:
C_{sw} = Concentration in surface water (µg/l); *calculated*
C_{gw} = Average concentration in groundwater (µg/l); *February 23 – 25, 2000 groundwater sampling event*
Q_{sw} = Harmonic Mean Flow or $Q_{7\text{-}10}$ (cubic feet/sec (cfs))
$Q_{7\text{-}10}$ = 7 day/10 year low flow; *Data from the United States Geological Survey, West Trenton, New Jersey station (closest gauging station to the site).*
Q_{gw} = Groundwater discharge rate (cubic feet/sec); *(equation 2)*

Q_{gw} is estimated as follows:

Equation 2:

$Q_{gw} = KIA$ Where: K = Hydraulic conductivity (*4.59 ft/day, the average hydraulic conductivity at the site based on the slug testing results*)

I = Hydraulic gradient (*0.0225, the average hydraulic gradient at the site based on the March 15, 2000 groundwater contour map*)

A = Cross sectional area of discharge to river (*41,200 ft^2, the cross sectional area of discharge to river assuming a 20 foot thick interface between groundwater and the river*)

3. Section 7.2, Exposure Characterization

URS/Dames & Moore evaluated the cumulative cancer and noncancer risk of exposure for a person standing outside coming in direct contact with exposed soil by way of incidental ingestion, dermal contact and inhalation of vapors and dust. This evaluation is included in the attached narrative titled "Evaluation of Cumulative Risk for the Soil Medium Assuming an Industrial Worker Exposure Scenario" with accompanying spreadsheet calculations (Attachment 2). The results show that the calculated cumulative cancer risk is within the one-in-ten thousand (10-4) to one-in-one million (10-6) USEPA risk range and the cumulative noncancer risk is below the USEPA hazard index of 1.

4. Section 7.2.8, Exposure During Construction

A narrative has been prepared to clarify the Construction Worker Exposure Calculations spreadsheets that were provided as Appendix N to the Combined Act 2 Report, May 31, 2000. The narrative is titled "Construction Worker Exposure Scenario" and is attached to this correspondence (Attachment 3).

-oOo-

We look forward to discussing these items and any further project concerns that PADEP may have during the meeting scheduled for Thursday, June 29, 2000.

Sincerely,

URS/DAMES & MOORE

for

Thomas R. Buggey, PG
Senior Geologist

Sharon H. Roberts
Project Hydrogeologist

cc: Paul Gotthold, EPA
Charles Barksdale, Sunoco, Inc.
Steven Coladonato, Sunoco, Inc.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION AND 1ST ORDER DECAY and RETARDATION

Project:	FPLE/Ssunoco		
Date:	03/14/2000	Prepared by:	Neil Laird
		Contaminant:	Benzene-MW-118

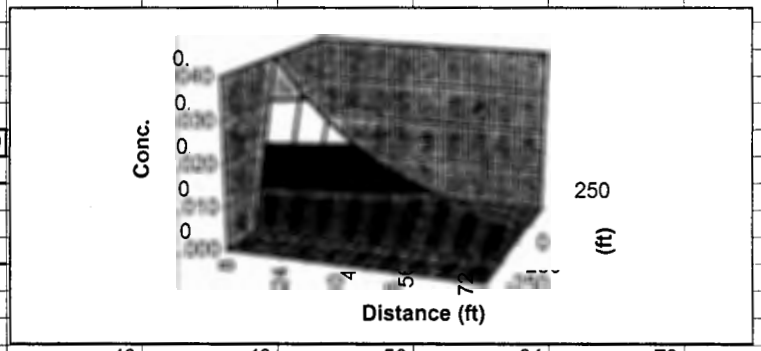
PA DEPARTMENT
OF ENVIRONMENTAL PROTECTION
QUICK_DOMENICO.XLS
SPREADSHEET APPLICATION OF
"AN ANALYTICAL MODEL FOR
MULTIDIMENSIONAL TRANSPORT OF A
DECAYING CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation

	X						
SOURCE CONC (MG/L)	DISTANCE TO LOCATION OF CONCERN (ft)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)
0.05	80	8	0.8	0.001	0.000959	100	20

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retardation (R)	V (=K*i/n*R) (ft/day)
5.63E-01	0.0225	0.2	1.8	58	2.50E-03	2.305	0.02749783

	y(ft)	z(ft)	Time (days)
80	0	0	10950

Projected Conc. at		80	0	0
at	10950	days		
0.005	mg/l			



AREAL MODEL CALCULATION DOMAIN

Length (ft) 80
Width (ft) 250

	8	16	24	32	40	48	56	64	72	80
250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.040	0.032	0.025	0.020	0.016	0.013	0.010	0.008	0.006	0.005
-125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION AND 1ST ORDER DECAY and RETARDATION

Project:	FPLE/Sunoco		
Date:	06/15/2000	Prepared by:	Neil Laird
		Contaminant:	Dichloromethane-MW-137

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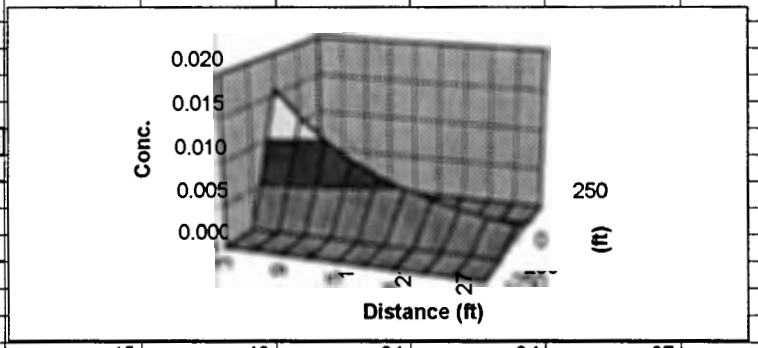
	X						
SOURCE CONC (MG/L)	DISTANCE TO LOCATION OF CONCERN (ft)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)
0.02	19	1.9	0.19	0.001	0.0123	100	20

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retardation (R)	V (=K*i/n*R) (ft/day)
2.61E+00	0.0225	0.3	1.7	16	5.00E-03	1.453333333	0.134741972

	y(ft)	z(ft)	Time (days)
	19	0	0
	19	0	10950



Projected Conc. at	19	0	0
at 10950 days			
0.004 mg/l			

AREAL MODEL CALCULATION DOMAIN	
Length (ft)	30
Width (ft)	250

	3	6	9	12	15	18	21	24	27	30
250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.016	0.012	0.010	0.008	0.006	0.005	0.004	0.003	0.002	0.002
-125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION AND 1ST ORDER DECAY and RETARDATION

Project:	FPLE/Ssunoco		
Date:	05/18/2000	Prepared by:	Jeffrey K. Wade
		Contaminant:	Trichloroethylene-MW145

X

SOURCE CONC (MG/L)	DISTANCE TO LOCATION OF CONCERN (ft)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)
0.048	35	3.5	0.35	0.001	0.000054795	100	20

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retardation (R)	V (=K*i/n*R) (ft/day)
5.63E-01	0.0022	0.2	1.8	93	2.50E-03	3.0925	0.00200401

y(ft)	z(ft)	Time (days)
35	0	0	10950

Projected Conc. at 35 0 0

at 10950 days

0.005 mg/l

AREAL MODEL DOMAIN

Length (ft) 150

Width (ft) 250

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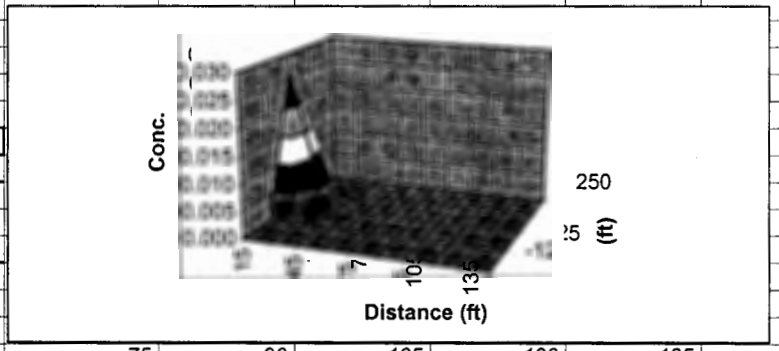
P.A. Domenico (1987)
Modified to Include Retardation



	15	30	45	60	75	90	105	120	135	150
250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.027	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION AND 1ST ORDER DECAY and RETARDATION

Project:	FPLE/Ssunoco							
Date:	05/18/2000	Prepared by:	Jeffrey K. Wade					
		Contaminant:	Bis(2-ethylhexyl) phthalate-MW145					
	X							
SOURCE	DISTANCE T	Ax	Ay	Az	LAMBDA	SOURCE	SOURCE	
CONC	LOCATION C	(ft)	(ft)	(ft)		WIDTH	THICKNESS	
(MG/L)	CONCERN (ft)			>=.001	day-1	(ft)	(ft)	
0.04	0.01	0.001	0.0001	0.001	0.00178082	100	20	
Hydraulic	Hydraulic		Soil Bulk		Frac.	Retard-	V	
Cond	Gradient	Porosity	Density	KOC	Org. Carb.	ation	(=K*i/n*R)	
(ft/day)	(ft/ft)	(dec. frac.)	(g/cm^3)			(R)	(ft/day)	
5.63E-01	0.0022	0.3	1.8	87000	2.50E-03	1306	3.1636E-06	
	y(ft)	z(ft)	Time (days)					
0.01	0	0	10950					
Projected Conc. at		0.01	0	0				
at	10950	days						
0.001	mg/l							
	AREAL	CALCULATION						
	MODEL	DOMAIN						
	Length (ft)	1						
	Width (ft)	250						

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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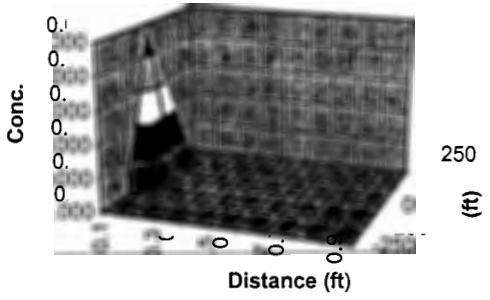

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION AND 1ST ORDER DECAY and RETARDATION

Project:	FPLE/Sunoco						
Date:	03/28/2000	Prepared by:	Neil Laird				
		Contaminant:	4-Methyiphenol (Cresol)-MW-143				
	X						
SOURCE CONC (MG/L)	DISTANCE TO LOCATION OF CONCERN (ft)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)
0.22	2	0.2	0.02	0.001	0.0141	100	42

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
2.29E-02	0.41	0.2	1.8	25	2.50E-03	1.5625	0.03005792

	y(ft)	z(ft)	Time (days)
2	0	0	10950

Projected Conc. at 2 0 0

at 10950 days

0.093 mg/l

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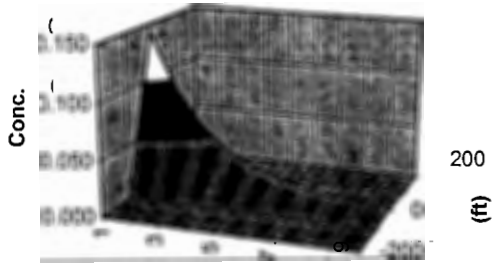

AREAL MODEL CALCULATION DOMAIN

Length (ft) 10

Width (ft) 200

	1	2	3	4	5	6	7	8	9	10
200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.143	0.093	0.060	0.039	0.025	0.016	0.011	0.007	0.005	0.003
-100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION AND 1ST ORDER DECAY and RETARDATION

Project:	FPLE/Ssunoco		
Date:	03/14/2000	Prepared by:	Neil Laird
		Contaminant:	Benzene-MW-141

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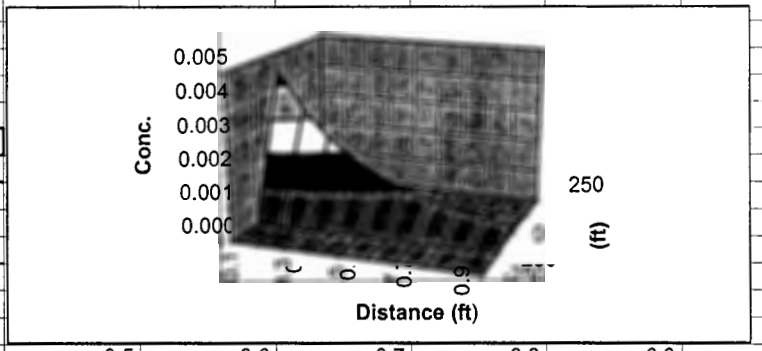
Modified to Include Retardation

	X						
SOURCE CONC (MG/L)	DISTANCE TO LOCATION OF CONCERN (ft)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)
0.006	0.1	0.01	0.001	0.001	0.000959	100	20

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retardation (R)	V (=K*i/n*R) (ft/day)
1.10E-02	0.013	0.2	1.8	58	2.50E-03	2.305	0.00031104

	y(ft)	z(ft)	Time (days)
	0.1	0	0	10950

Projected Conc. at		0.1	0	0
at	10950	days		
0.004	mg/l			



	AREAL MODEL	CALCULATION DOMAIN
	Length (ft)	1
	Width (ft)	250

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000
-125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

EVALUATION OF CUMULATIVE RISK FOR THE SOIL MEDIUM ASSUMING AN INDUSTRIAL WORKER EXPOSURE SCENARIO

Objective

An evaluation of cumulative cancer and noncancer risk resulting from assumed exposure to multiple constituents in soil by way of direct contact during daily industrial activities was desired on a parcel of property at the Sunoco, Inc. (R&M) Marcus Hook facility, Phillips Island site. Soil is the sole environmental medium in this evaluation. Assumed exposure of an industrial worker due to direct contact with soil in an outdoor setting is the exposure scenario evaluated in the text to follow.

Approach Used for the Analysis

The general algorithms and exposure assumptions for calculation of risk-based reference concentrations assuming nonresidential exposure (i.e., continued industrial use of the parcel) were obtained from the Pennsylvania Land Recycling Program, which is known as Act 2 (PADEP, 1997). Additional algorithm components, such as a dermal component, were obtained from other sources (TNRCC, 1999; 1997). To perform the cumulative risk analysis, risk-based reference concentrations were calculated for simultaneous exposure via inhalation of vapors and dust from the area, dermal contact with the surface soil, and incidental ingestion of surface soil. Consistent with the method used to establish statewide health standards in Section 250.305 of Act 2, nonresidential soils are defined as 0-2 feet in depth for purposes of evaluation of the ingestion exposure route (although not required under Act 2, the risk assessor also incorporated the dermal exposure route as well). For evaluation of the vapor and dust exposure pathways under a nonresidential setting, in an approach consistent with the method used to establish statewide health standard in Section 250.305 of Act 2, the top 15 feet of soil was evaluated. This cumulative risk evaluation conservatively included consideration of the top 20 feet of soil as subsurface soil because the proposed future use of the parcel includes leveling operations in some sections of the parcel that could change the topography by a foot or more. The proposed finished grade of the main section of the proposed future use of the parcel is 24.5 feet (refinery datum), which would result in less than five feet of reduction in current elevation. Section 250.1 of Act 2 defines volatile constituents as those constituents having a Henry's Law constant of 1E-05 atm-m3/mol or greater and a molecular weight of 200 g/mol or less.

A spreadsheet attached to this evaluation contains risk-based reference values for an industrial worker assumed to be exposed for 180 days/year over a 25-year working lifetime (exposure assumptions per 250.305 of Act 2). For the cumulative risk analysis, both cancer-based and noncancer-based reference concentrations were needed. For carcinogenic constituents, the reference concentrations presented in the spreadsheet

correspond to a one-in-one million cancer risk. For noncarcinogenic constituents, the reference concentrations correspond to a hazard index of 1.

Toxicity data needed for calculation of risk-based reference concentrations were obtained from EPA's Integrated Risk Information System (IRIS; EPA, 2000a). Missing toxicity data were supplemented with data obtained from EPA's Health Effects Assessment Summary Tables (HEAST; EPA, 1995). Provisional toxicity data were obtained from Region III EPA's Risk-Based Concentration Table (EPA, 2000b). Additional toxicity data were obtained from the Texas Natural Resource Conservation Commission's (TNRCC's) Texas Risk Reduction Program (TRRP; TNRCC, 1999). Gastrointestinal absorption values needed for conversion of oral toxicity data to dermal toxicity data were obtained from the TNRCC's TRRP (TNRCC, 1999).

Cumulative cancer and noncancer risks for multiple constituents in soil are contained in an accompanying spreadsheet. Cumulative risk for carcinogenic constituents was calculated by dividing the maximum detected constituent concentration detected in site soil by reference concentrations that correspond to a one-in-one million cancer risk (i.e., 1E-06 cancer risk) and multiplying the resulting value by 1E-06. The resulting value corresponds to the cancer risk presented by assumed exposure to a single carcinogenic constituent by way of inhalation, dermal contact, and ingestion. As EPA (1991) considers all carcinogenic endpoints to be the same, cancer risk is additive regardless of the site of tumor development. Thus, cancer risk presented by each constituent present in soil was summed to yield a total cancer risk.

To further explain the method used in calculating cumulative risk, the following example calculation is presented:

Alpha-hexachlorocyclohexane (also known as alpha-BHC), a nonvolatile constituent, is present in surface soil at 49 milligrams per kilogram (mg/kg). Benzene, a volatile constituent, is present in surface soil at 0.27 mg/kg and in subsurface soil at 21 mg/kg. The 1E-06 cancer risk reference value for inhalation of benzene from surface and subsurface soil is 22.9 mg/kg. A reference concentration was not established for the dermal route because volatile constituents were assumed to volatilize from soil deposited on the skin before dermal penetration could occur (TNRCC, 1999). The surface soil ingestion reference for benzene is 274 mg/kg. The inhalation, dermal, and ingestion reference values for alpha-BHC in surface soil (surface soil only is relevant for alpha-BHC because the constituent does not meet the Act 2 volatility criteria) are 70,400 mg/kg, 1.59 mg/kg, and 1.26 mg/kg, respectively. Total cancer risk for benzene is calculated by dividing the greater of the surface and the subsurface soil concentration (in this case, 21 mg/kg) by the inhalation reference value that corresponds to a 1E-06 cancer risk (i.e., 22.9 mg/kg) and multiplying the resulting value by 1E-06. The result is 21 mg/kg/22.9 mg/kg x 1E-06 = 9.15E-07 benzene cancer risk for the inhalation route alone. Adding the cancer risk due to exposure to benzene in soil by way of ingestion, a cancer risk of 9.85E-10 is generated (0.27 mg/kg/274 mg/kg x 1E-06 = 9.85E-10 cancer risk due to ingestion). Adding the two benzene cancer risk values together, a total cancer risk due to exposure to benzene alone is 9.15E-07 + 9.85E-10 = 9.16E-07.

Performing the same calculation for alpha-BHC, a total cancer risk due to assumed exposure to alpha-BHC in surface soil by way of inhalation of dust (the constituent is not volatile), dermal contact, and ingestion is 6.96E-05 (risks of 6.96E-10 for inhalation of dust, 3.08E-05 for dermal contact, and 3.88E-05 for ingestion = 6.96E-05 cancer risk). Adding the total cancer risk calculated for benzene, 9.16E-07, to the total cancer risk calculated for alpha-BHC, 6.96E-05, a total cumulative cancer risk of 7.05E-05 is obtained. This approach is the same used to generate cumulative cancer risk in the attached spreadsheet for approximately 20 carcinogenic constituents detected in soil at the site.

For noncarcinogenic constituents, cumulative noncancer risk was generated by dividing the maximum detected constituent concentration in soil by the risk-based reference concentration that corresponded to a hazard index of one. The resulting value represented the hazard index for an individual constituent assuming exposure by way of inhalation, dermal contact, and ingestion. Because EPA (1991) recognizes that noncarcinogenic constituents may exert toxic action on different target organs, cumulative noncancer risk conventionally is generated by summing hazard indices for individual constituents exerting their toxic effects on the same target organ to result in a total hazard index. Using mercury and cadmium to illustrate the calculation process, the following example hazard index calculation results: For mercury, which is present in surface soil at 4.3 mg/kg, the noncancer reference values are 12,220,000 mg/kg for inhalation of dust from soil, 753 mg/kg for dermal exposure, and 852 mg/kg for ingestion of soil containing mercury. The noncancer reference values for cadmium, present in surface soil at 5.0 mg/kg, are 8,090,000 mg/kg for the inhalation route, 896 mg/kg for the dermal route, and 2,840 mg/kg for the ingestion route. Dividing the surface soil concentration by the mercury inhalation reference value that corresponds to a hazard index of 1 (more correctly, a hazard quotient, because a single constituent and a single route of exposure are involved), a hazard quotient of 3.52E-07 results (i.e., 4.3 mg/kg/12,220,000 mg/kg = 3.52E-07). Adding the hazard quotients due to dermal contact and ingestion of surface soil containing mercury, which are 5.71E-03 and 5.05E-03, respectively, to the hazard quotient for inhalation of mercury, a hazard index for exposure to mercury alone is 1.08E-02 (3.52E-07 + 5.71E-03 + 5.05E-03 = 1.08E-02). Performing the same calculations for cadmium, a hazard index of 7.34E-03 results for that constituent. Assuming that both mercury and cadmium act on the same target organ, a cumulative hazard index of 1.81E-02 results for assumed concurrent exposure to the two constituents in soil (1.08E-02 + 7.34E-03 = 1.81E-02). This approach is the same used to generate cumulative noncancer risk in the attached spreadsheet for 35 constituents detected in soil at the Facility.

Human Health Protection Goals

Section 250.402 of Act 2 (PADEP, 1997) specifies that the human health protection goals required in the State of Pennsylvania consist of a cumulative excess cancer risk between 1E-06 and 1E-04 (i.e., one excess cancer per 10,000) and a cumulative hazard index of 1.

These health protection goals are used as the basis for comparison with the cumulative risk analysis in the attached spreadsheet. From the example calculations above with carcinogenic constituents, the cumulative risk of benzene and alpha-BHC are within the cumulative excess cancer risk range. For noncarcinogenic constituents, assuming that only cadmium and mercury were present in the soil, there would be no need for evaluation of remedial options because the cumulative hazard index was less than 1.

Result of the Cumulative Risk Analysis

The results of the cumulative risk analysis are presented in Table 1. The spreadsheet containing the details of the cumulative risk analysis is attached. From Table 1, the upper bound health protection goal for carcinogenic constituents (i.e., 1E-04) and the health protection goal for noncarcinogenic constituents (i.e., 1) were not exceeded. The primary contributor to cumulative cancer risk above the lower end of the health protection goal (i.e., 1E-06 cancer risk) was alpha-BHC, which contributed 84 percent of the total cumulative cancer risk.

Table 1 - Result of the Cumulative Risk Analysis, Parcel on Sunoco Marcus Hook, Phillips Island

Target Cumulative Cancer Risk	Total Cumulative Cancer Risk	Primary Contributor to Cancer Risk
1E-04	8.31E-05	alpha-BHC
Target Cumulative Noncancer Risk	Total Cumulative Noncancer Risk	Primary Contributor to Noncancer Risk
1	0.175	Not applicable

Uncertainty Statement

The cumulative risk evaluation for the soil medium did not include data collected from saturated soil. Saturated soil typically is addressed as a groundwater issue; thus, no consideration was given to constituent presence in saturated soil. This analysis did include data for unsaturated soil collected from the 0 to 20-foot depth. While applying an approach consistent to the Act 2 statewide health standards requires evaluation of only the top 15 feet of soil for potential direct contact (by way of inhalation of vapors) anticipated minor land leveling activities on a portion of the parcel caused extension of the Act 2 depth to a more conservative depth of 20 feet. [For all parameters except for benzene and dichloromethane detected in one sample (1,700 mg/kg and 67 JB mg/kg, respectively, in B-PH8, 24-26 feet bgs), there were no concentrations below 20 feet bgs greater than concentrations above 20 feet bgs.]

Although Act 2 does not require evaluation of the dermal route of exposure for constituents in soil, the risk assessor included the dermal route of exposure because of the presence of semivolatile constituents detected in surface soil. Semivolatile constituents

are the most likely constituents to penetrate intact skin when the soil medium is considered. However, including the dermal pathway roughly doubled the risk over the soil ingestion route alone. Hence, the total cancer risk calculated for alpha-BHC, a pesticide that has the properties of a semivolatile constituent, is increased by approximately 2-fold. In addition, use of an assumed completely exposed head, arms, and hands likely is conservative in a typical plant setting, where workers are required to wear protective clothing such as hard hats and fire-resistant long-sleeve coveralls.

Yet another source of uncertainty introduced into the cumulative risk analysis is the use of maximum detected concentrations in surface or subsurface soils rather than the use of statistically-based upper bound constituent concentrations. Assuming that the data were suitable for statistical representation, it is probable that use of maximum detected concentrations overstates the true risk potential.

Summary

The result of a conservative cumulative risk analysis performed for the land parcel of interest on the Sunoco, Inc. Marcus Hook, Phillips Island site was that cumulative cancer risk was within the range of risks constituting the health protection goal for lands in Pennsylvania. Alpha-BHC in surface soil was the primary contributor to cancer risk. Cumulative noncancer risk was less than the target health protection goal of a hazard index of 1

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	INDUSTRIAL WORKER SCENARIO																	
2	SUN MARCUS HOOK FACILITY																	
3	EXPOSURE BY WAY OF INGESTION, VAPOR/DUST INHALATION, AND DERMAL CONTACT WITH SOIL IN AN OUTDOOR SETTING																	
4																		
5																		
6	Carcinogenic Constituents																	
7	C (mg/kg)	=	RL x AT x BW x 365 days/yr x TF															
8			(((SFi x EF x ET x IFadj x BW) + (SFd/RfD x 10-6 kg/mg x EF x ED x SA x AF x ABS x TF) + (SFo/RfD0 x 10-6 kg/mg x ET x ED x IRs xTF))															
9																		
10	Noncarcinogenic Constituents																	
11	C (mg/kg)	=	RL x AT x BW x 365 days/yr x TF															
12			(((1/RfDi x EF x ET x IRa x ED) + (SFd/RfD x 10-6 kg/mg x EF x ED x SA x AF x ABS x TF) + (SFo/RfD0 x 10-6 kg/mg x ET x ED x IRs xTF))															
13																		
14	Assumptions									VALUE								
15	C	=	risk-based constituent concentration in soil, mg/kg							calculated								
16	RL	=	reference cancer risk level							1.00E-06								
17			reference hazard index							1								
18	AT	=	averaging time for carcinogens, yr							70	PA Act 2							
19			averaging time for noncarcinogens (equals ED), yr							25	PA Act 2							
20	BW	=	adult body weight, kg							70	PA Act 2							
21	EF	=	exposure frequency for a worker, days/yr							180	PA Act 2							
22	ED	=	exposure duration for a worker, yr							25	PA Act 2							
23	SA	=	exposed skin surface area, cm2							3300	head + forearms + hands TNRCC 1997							
24	AF	=	dermal soil adherence factor, unitless							0.12	TNRCC 1997							
25	ABS	=	dermal absorption default value for volatile organic constituents							0	TNRCC 1997							
26			dermal absorption default value for semivolatile organic constituents							0.1	TNRCC 1997							
27			dermal absorption default value for inorganic constituents							0.01	TNRCC 1997							
28	IRa	=	inhalation rate for a worker, m3/day							1.25	PA Act 2							
29	IRs	=	incidental soil ingestion rate for a worker, mg/day							50	PA Act 2; EPA, 1991							
30	IFadj	=	inhalation factor, m3-yr/kg-hr							0.4								
31	RfDo	=	oral reference dose, mg/kg-day							chem-specific								
32	RfDi	=	inhalation reference dose, mg/kg-day							chem-specific								
33	RfDd	=	dermal reference dose, mg/kg-day							chem-specific								
34	SFi	=	inhalation cancer slope factor, (mg/kg-day)-1							chem-specific								
35	SFd	=	dermal cancer slope factor, (mg/kg-d)-1							chem-specific								
36	SFo	=	oral cancer slope factor, (mg/kg-day)-1							chem-specific								
37	ET	=	exposure time, hr/day							8								
38	TF	=	transport factor for volatile constituents, mg/kg/mg/m3							chem-specific		PA Act 2						
39		=	for particulates, mg/kg/mg/m3							1.00E+10	PA Act 2							
40																		
41	PA Act 2. Land Recycling Program. 1997.																	
42	TNRCC, 1997. Clarifications	Petroleum Storage Tank Division. to PST Corrective Action Coordinators. March 6, 1997.																
43																		
44	EPA, 1996. Soil screening Guidance: User's Guide. EPA/540/R-96/018.																	
45	EPA, 1991. Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors". OSWER Directive9285.6-03.																	
46	TNRCC, 1999. Texas Risk Reduction Program.																	
47											Cancer	Cancer	Cancer	Cancer	Noncancer	Noncancer	Noncancer	Noncancer
48											Inhalation	Dermal	Ingestion	Cumulative	Inhalation	Dermal	Ingestion	Cumulative
49	Constituent	SFi	RfDi	CSFo	RfDo	GI Absorp	CSFd	RfDd	ABS	TF	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
50	Acetone				1.00E-01	NA		NA	0	1.50E+04		0				0	2.84E+05	2.84E+05
51	Bis(2-chloroethyl)ether	1.10E+00		1.10E+00		NA	NA		0	1.49E+04	6.01E-01	0	7.23E+00	5.55E-01		0		
52	Benzene	2.90E-02	1.70E-03	2.90E-02	3.00E-03	NA	NA	NA	0	1.50E+04	2.29E+01	0	2.74E+02	2.12E+01	3.62E+02	0	8.52E+03	3.47E+02
53	Bromomethane		1.40E-03		1.40E-03	NA		NA	0	1.50E+04		0			2.98E+02	0	3.97E+03	2.77E+02
54	2-Butanone (MEK)		2.86E-01		6.00E-01	NA		NA	0	1.51E+04		0			6.13E+04	0	1.70E+06	5.92E+04
55	Carbon Disulfide		2.00E-01		1.00E-01	NA		NA	0	1.51E+04		0			4.29E+04	0	2.84E+05	3.72E+04
56	Chlorobenzene		1.70E-02		2.00E-02	NA		NA	0			0				0	5.68E+04	5.68E+04
57	Chloroethane		2.90E+00	2.90E-03	4.00E-01	NA	NA	NA	0	1.50E+04		0	2.74E+03	2.74E+03	6.17E+05	0	1.14E+06	4.00E+05
58	Chloroform	8.10E-02	8.60E-05	6.10E-03	1.00E-02	NA	NA	NA	0	1.50E+04	8.21E+00	0	1.30E+03	8.16E+00	1.83E+01	0	2.84E+04	1.83E+01
59	Cumene (isopropylbenzene)		1.10E-01		1.00E-01	NA		NA	0	1.51E+04		0			2.36E+04	0	2.84E+05	2.18E+04
60	1,1-Dichloroethane		1.40E-01		1.00E-01	NA		NA	0	1.50E+04					2.98E+04	0	2.84E+05	2.70E+04
61	1,2-Dichloroethane	9.10E-02	1.40E-03	9.10E-02	3.00E-02	NA	NA	NA	0	1.50E+04	7.31E+00	0	8.74E+01	6.75E+00	2.98E+02	0	8.52E+04	2.97E+02
62	cis-1,2-Dichloroethene				1.00E-02	NA		NA	0	1.50E+04		0				0	2.84E+04	2.84E+04
63	Ethylbenzene		2.90E-01		1.00E-01	NA		NA	0	1.50E+04		0			6.17E+04	0	2.84E+05	5.07E+04
64	Methylene Chloride	1.65E-03	8.60E-01	7.50E-03	6.00E-02	NA	NA	NA	0	1.50E+04	4.03E+02	0	1.06E+03	2.92E+02	1.83E+05	0	1.70E+05	8.82E+04

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
65	Methyl-tert-butyl ether		8.57E-01			NA			0	1.51E+04		0			1.84E+05	0		1.84E+05
66	Tetrachloroethene	2.00E-03	1.40E-01	5.20E-02	1.00E-02	NA	NA	NA	0	1.50E+04	3.33E+02	0	1.53E+02	1.05E+02	2.98E+04	0	2.84E+04	1.45E+04
67	Toluene		1.14E-01		2.00E-01	NA		NA	0	1.50E+04		0			2.43E+04	0	5.68E+05	2.33E+04
68	Trichloroethene	6.00E-03		1.10E-02	6.00E-03	NA	NA	NA	0	1.50E+04	1.11E+02	0	7.23E+02	9.61E+01		0	1.70E+04	1.70E+04
69	Xylenes				2.00E+00	NA		NA	0	1.50E+04		0				0	5.68E+06	5.68E+06
70	Aniline		2.90E-04	5.70E-03	7.00E-03	5.00E-01	5.70E-03	7.00E-03	0.1			1.76E+03	1.39E+03	7.78E+02	4.12E+07	2.51E+04	1.99E+04	1.11E+04
71	Anthracene				3.00E-01	8.90E-01		3.00E-01	0.1							1.08E+06	8.52E+05	4.75E+05
72	Benzo(a)anthracene			7.30E-01		8.90E-01	7.30E-01		0.1			1.37E+01	1.09E+01	6.08E+00				
73	Benzo(b)fluoranthene			7.30E-01		8.90E-01	7.30E-01		0.1			1.37E+01	1.09E+01	6.08E+00				
74	Benzo(k)fluoranthene			7.30E-02		8.90E-01	7.30E-02		0.1			1.37E+02	1.09E+02	6.08E+01				
75	Benzo(a)pyrene			7.30E+00		8.90E-01	7.30E+00		0.1			1.37E+00	1.09E+00	6.08E-01				
76	Benzo(g,h,i)perylene				3.00E-02	8.90E-01		3.00E-02	0.1							1.08E+05	8.52E+04	4.75E+04
77	Bis(2-ethylhexyl)phthalate	1.40E-02		1.40E-02	2.00E-02	**1.90E-01**	7.37E-02	3.80E-03	0.1		3.17E+07	1.36E+02	5.68E+02	1.10E+02		1.36E+04	5.68E+04	1.10E+04
78	Chrysene			7.30E-03		8.90E-01	7.30E-03		0.1			1.37E+03	1.09E+03	6.08E+02				
79	Fluoranthene				4.00E-02	8.90E-01		4.00E-02	0.1							1.43E+05	1.14E+05	6.34E+04
80	Indeno(1,2,3-cd)pyrene			7.30E-01		8.90E-01	7.30E-01		0.1			1.37E+01	1.09E+01	6.08E+00				
81	2-Methylnaphthalene				2.00E-02	8.90E-01		2.00E-02	0.1							7.17E+04	5.68E+04	3.17E+04
82	Naphthalene		9.00E-04		2.00E-02	8.90E-01		2.00E-02	0.1						1.28E+08	7.17E+04	5.68E+04	3.17E+04
83	2-Nitroaniline		5.70E-05		3.00E-04	5.00E-01		3.00E-04	0.1						8.09E+06	1.08E+03	8.52E+02	4.75E+02
84	3-Nitroaniline				3.00E-04	5.00E-01		3.00E-04	0.1							1.08E+03	8.52E+02	4.75E+02
85	4-Nitroaniline				3.00E-03	5.00E-01		3.00E-03	0.1							1.08E+04	8.52E+03	4.75E+03
86	n-Nitrosodiphenylamine			4.90E-03		**2.50E-01**	1.96E-02		0.1			5.12E+02	1.62E+03	3.89E+02				
87	Phenanthrene				3.00E-02	8.90E-01		3.00E-02	0.1							1.08E+05	8.52E+04	4.75E+04
88	Pyrene				3.00E-02	8.90E-01		3.00E-02	0.1							1.08E+05	8.52E+04	4.75E+04
89	Aroclor 1016	7.00E-02		7.00E-02	7.00E-05	8.10E-01	7.00E-02		0.1		6.34E+06	1.43E+02	1.14E+02	6.34E+01			1.99E+02	1.99E+02
90	Aroclor 1260	2.00E+00		2.00E+00		8.10E-01	2.00E+00		0.1		2.22E+05	5.02E+00	3.97E+00	2.22E+00				
91	4,4'-DDD			2.40E-01		7.00E-01	2.40E-01		0.1			4.18E+01	3.31E+01	1.85E+01				
92	4,4'-DDE			3.40E-01		7.00E-01	3.40E-01		0.1			2.95E+01	2.34E+01	1.30E+01				
93	4,4'-DDT	3.40E-01		3.40E-01	5.00E-04	7.00E-01	3.40E-01	5.00E-04	0.1		1.30E+06	2.95E+01	2.34E+01	1.30E+01		1.79E+03	1.42E+03	7.92E+02
94	alpha-BHC	6.30E+00		6.30E+00		9.70E-01	6.30E+00		0.1		7.04E+04	1.59E+00	1.26E+00	7.04E-01				
95	beta-BHC	1.80E+00		1.80E+00		9.70E-01	1.80E+00		0.1		2.46E+05	5.58E+00	4.42E+00	2.46E+00				
96	delta-BHC								0.1									
97	gamma-BHC (Lindane)			1.30E+00	3.00E-04	9.70E-01	1.30E+00	3.00E-04	0.1			7.72E+00	6.11E+00	3.41E+00		1.08E+03	8.52E+02	4.75E+02
98	gamma-Chlordane	3.50E-01	2.00E-04	3.50E-01	5.00E-04	8.00E-01	3.50E-01	5.00E-04	0.1		1.27E+06	2.87E+01	2.27E+01	1.27E+01	2.84E+07	1.79E+03	1.42E+03	7.92E+02
99	Dieldrin	1.60E+01		1.60E+01	5.00E-05	5.00E-01	1.60E+01	5.00E-05	0.1		2.77E+04	6.27E-01	4.97E-01	2.77E-01		1.79E+02	1.42E+02	7.92E+01
100	Endrin Aldehyde				3.00E-04	5.00E-01		3.00E-04	0.1							1.08E+03	8.52E+02	4.75E+02
101	Heptachlor Epoxide	9.10E+00		9.10E+00	1.30E-05	7.20E-01	9.10E+00	1.30E-05	0.1		4.87E+04	1.10E+00	8.74E-01	4.87E-01		4.66E+01	3.69E+01	2.06E+01
102	Arsenic	1.50E+01		1.50E+00	3.00E-04	9.50E-01	1.50E+00	3.00E-04	0.01		2.96E+04	6.69E+01	5.30E+00	4.91E+00		1.08E+04	8.52E+02	7.89E+02
103	Barium		1.40E-04		7.00E-02	**7.00E-02**		4.90E-03	0.01						1.99E+07	1.76E+05	1.99E+05	9.28E+04
104	Beryllium	8.40E+00	5.70E-06		2.00E-03	**7.00E-03**		1.40E-05	0.01		5.28E+04			5.28E+04	8.09E+05	5.02E+02	5.68E+03	4.61E+02
105	Cadmium	6.30E+00	5.70E-05		1.00E-03	**2.50E-02**		2.50E-05	0.01		7.04E+04			7.04E+04	8.09E+06	8.96E+02	2.84E+03	6.81E+02
106	Chromium (III)				1.50E+00	**1.30E-02**		1.95E-02	0.01							6.99E+05	4.26E+06	6.00E+05
107	Copper				4.00E-02	5.70E-01		4.00E-02	0.01							1.43E+06	1.14E+05	1.05E+05
108	Cyanide (total)				2.00E-02	5.00E-01		2.00E-02	0.01							7.17E+05	5.68E+04	5.26E+04
109	Lead																	
110	Mercury		8.60E-05		3.00E-04	**7.00E-02**		2.10E-05	0.01						1.22E+07	7.53E+02	8.52E+02	4.00E+02
111	Nickel				2.00E-02	**4.00E-02**		8.00E-04	0.01							2.87E+04	5.68E+04	1.91E+04
112	Selenium				5.00E-03	5.00E-01		5.00E-03	0.01							1.79E+05	1.42E+04	1.32E+04
113	Silver				5.00E-03	**4.00E-02**		2.00E-04	0.01							7.17E+03	1.42E+04	4.76E+03
114	Zinc				3.00E-01	**2.00E-01**		6.00E-02	0.01							2.15E+06	8.52E+05	6.10E+05
115																		
116	Toxicity data, in order of preference for use, from IRIS, HEAST, Region III EPA, TNRCC TRRP																	
117	Gastrointestinal absorption data from TNRCC TRRP																	

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	CUMULATIVE RISK ANALYSIS												
2	INDUSTRIAL WORKER SCENARIO - EXPOSURE TO SOIL IN OUTDOOR SETTING												
3	SUN MARCUS HOOK FACILITY												
4													
5													
6													
7	**Cumulative Risk Analysis of Carcinogenic Constituents**												
8				Cancer	Cancer	Cancer							
9		Maximum	Maximum	Inhalation	Dermal	Oral	Cumulative	Cumulative	Cumulative	Total			
10		Surface Soil	Subsurface	Reference	Reference	Reference	Cancer	Cancer	Cancer	Cumulative			
11		Conc'n	Soil Conc'n	Conc'n	Conc'n	Conc'n	Inhalation	Dermal	Oral	Cancer			
12	Constituent	(mg/kg)	(mg/kg) a)	(mg/kg)	(mg/kg)	(mg/kg)	Risk	Risk	Risk	Risk			
13	Acetone	8.00E-01	2.80E+00										
14	Bis(2-chloroethyl)ether			6.01E-01		7.23E+00							
15	Benzene	2.70E-01	2.10E+01	2.29E+01		2.74E+02	9.15E-07		9.85E-10	9.16E-07			
16	Bromomethane		1.20E-02										
17	2-Butanone (MEK)	3.50E-01	3.50E-01										
18	Carbon Disulfide	5.30E-02	3.30E-01										
19	Chlorobenzene	7.40E-02	6.30E-02										
20	Chloroethane		4.40E-01			2.74E+03							
21	Chloroform	4.00E-03	1.00E-02	8.21E+00		1.30E+03	1.22E-09		3.07E-12	1.22E-09			
22	Cumene (isopropylbenzene)	1.60E-01	6.90E+00										
23	1,1-Dichloroethane		9.00E-03										
24	1,2-Dichloroethane	5.00E-03		7.31E+00		8.74E+01	6.84E-10		5.72E-11	7.41E-10			
25	cis-1,2-Dichloroethene		1.60E-02										
26	Ethylbenzene	9.70E-02	3.90E+01										
27	Methylene Chloride	2.60E-01	3.30E+00	4.03E+02		1.06E+03	8.18E-09		2.45E-10	8.43E-09			
28	Methyl-tert-butyl ether	6.00E-03	4.00E-03										
29	Tetrachloroethene		5.00E-03	3.33E+02		1.53E+02	1.50E-11			1.50E-11			
30	Toluene	1.50E-01	2.10E+00										
31	Trichloroethene		1.10E-02	1.11E+02		7.23E+02	9.92E-11			9.92E-11			
32	Xylenes	1.70E-01	7.10E+01										
33	Aniline		NA b)		1.76E+03	1.39E+03							
34	Anthracene	4.40E+00	NA										
35	Benzo(a)anthracene	6.50E+00	NA		1.37E+01	1.09E+01		4.73E-07	5.97E-07	1.07E-06			
36	Benzo(b)fluoranthene		NA		1.37E+01	1.09E+01							
37	Benzo(k)fluoranthene		NA		1.37E+02	1.09E+02							
38	Benzo(a)pyrene		NA		1.37E+00	1.09E+00							
39	Benzo(g,h,i)perylene	3.70E-01	NA										
40	Bis(2-ethylhexyl)phthalate	3.90E+00	NA	3.17E+07	1.36E+02	5.68E+02	1.23E-13	2.86E-08	6.87E-09	3.55E-08			
41	Chrysene	9.70E-01	NA		1.37E+03	1.09E+03		7.06E-10	8.91E-10	1.60E-09			
42	Fluoranthene	5.80E-01	NA										
43	Indeno(1,2,3-cd)pyrene	2.80E-01	NA		1.37E+01	1.09E+01		2.04E-08	2.57E-08	4.61E-08			
44	2-Methylnaphthalene	2.30E+00	NA										
45	Naphthalene	1.50E+00	NA										
46	2-Nitroaniline		NA										
47	3-Nitroaniline		NA										
48	4-Nitroaniline		NA										
49	n-Nitrosodiphenylamine	4.40E+00	NA		5.12E+02	1.62E+03		8.59E-09	2.71E-09	1.13E-08			
50	Phenanthrene	1.80E+01	NA										
51	Pyrene	6.50E+00	NA										
52	Aroclor 1016		NA	6.34E+06	1.43E+02	1.14E+02							
53	Aroclor 1260	1.30E-01	NA	2.22E+05	5.02E+00	3.97E+00	5.86E-13	2.59E-08	3.27E-08	5.86E-08			
54	4,4'-DDD	2.30E+01	NA		4.18E+01	3.31E+01		5.50E-07	6.94E-07	1.24E-06			
55	4,4'-DDE	1.30E-01	NA		2.95E+01	2.34E+01		4.40E-09	5.56E-09	9.96E-09			
56	4,4'-DDT	4.20E+01	NA	1.30E+06	2.95E+01	2.34E+01	3.22E-11	1.42E-06	1.80E-06	3.22E-06			
57	alpha-BHC	4.90E+01	NA	7.04E+04	1.59E+00	1.26E+00	6.96E-10	3.08E-05	3.88E-05	6.96E-05			
58	beta-BHC	6.50E+00	NA	2.46E+05	5.58E+00	4.42E+00	2.64E-11	1.17E-06	1.47E-06	2.64E-06			
59	delta-BHC	3.30E-02	NA										
60	gamma-BHC (Lindane)		NA		7.72E+00	6.11E+00							
61	gamma-Chlordane	2.80E-03	NA	1.27E+06	2.87E+01	2.27E+01	2.21E-15	9.76E-11	1.23E-10	2.21E-10			
62	Dieldrin		NA	2.77E+04	6.27E-01	4.97E-01							
63	Endrin Aldehyde		NA										
64	Heptachlor Epoxide	1.80E-03	NA	4.87E+04	1.10E+00	8.74E-01	3.69E-14	1.63E-09	2.06E-09	3.69E-09			
65	Arsenic	2.10E+01	NA	2.96E+04	6.69E+01	5.30E+00	7.10E-10	3.14E-07	3.96E-06	4.28E-06			
66	Barium	2.60E+02	NA										
67	Beryllium	2.30E+00	NA	5.28E+04			4.36E-11			4.36E-11			
68	Cadmium	5.00E+00	NA	7.04E+04			7.10E-11			7.10E-11			
69	Chromium (III)	3.70E+02	NA										
70	Copper	2.70E+02	NA										
71	Cyanide (total)		NA										
72	Lead	2.50E+02	NA										
73	Mercury	4.30E+00	NA										
74	Nickel	5.40E+01	NA										
75	Selenium	1.00E+01	NA										
76	Silver	3.90E+00	NA					GRAND TOTAL		8.31E-05	Cumulative cancer risk		
77	Zinc	7.60E+02	NA										
78	a) = Unsaturated subsurface soil data used. Saturated soil data not used.												
79	b) not applicable, as constituent does not meet Pennsylvania Act 2 definition of volatility												
80													
81													
82													
83													
84	**Cumulative Risk Analysis of Noncarcinogenic Constituents**												
85				Noncancer	Noncancer	Noncancer							
86		Maximum	Maximum	Inhalation	Dermal	Oral	Cumulative	Cumulative	Cumulative	Total			
87		Surface Soil	Soil Column	Reference	Reference	Reference	Noncancer	Noncancer	Noncancer	Cumulative			

	A	B	C	D	E	F	G	H	I	J	K	L	M
88		Conc'n	Conc'n	Conc'n	Conc'n	Conc'n	Inhalation	Dermal	Oral	Noncancer			
89	Constituent	(mg/kg)	(mg/kg) a)	(mg/kg)	(mg/kg)	(mg/kg)	Risk	Risk	Risk	Risk			
90	Acetone	8.00E-01	2.80E+00			2.84E+05			2.82E-06	2.82E-06			
91	Bis(2-chloroethyl)ether												
92	Benzene	2.70E-01	2.10E+01	3.62E+02		8.52E+03	5.80E-02		3.17E-05	5.80E-02			
93	Bromomethane		1.20E-02	2.98E+02		3.97E+03	4.03E-05			4.03E-05			
94	2-Butanone (MEK)	3.50E-01	3.50E-01	6.13E+04		1.70E+06	5.71E-06		2.05E-07	5.92E-06			
95	Carbon Disulfide	5.30E-02	3.30E-01	4.29E+04		2.84E+05	7.70E-06		1.87E-07	7.88E-06			
96	Chlorobenzene	7.40E-02	6.30E-02			5.68E+04			1.30E-06	1.30E-06			
97	Chloroethane		4.40E-01	6.17E+05		1.14E+06	7.13E-07			7.13E-07			
98	Chloroform	4.00E-03	1.00E-02	1.83E+01		2.84E+04	5.46E-04		1.41E-07	5.46E-04			
99	Cumene (isopropylbenzene)	1.60E-01	6.90E+00	2.36E+04		2.84E+05	2.93E-04		5.64E-07	2.93E-04			
100	1,1-Dichloroethane		9.00E-03	2.98E+04		2.84E+05	3.02E-07			3.02E-07			
101	1,2-Dichloroethane	5.00E-03		2.98E+02		8.52E+04	1.68E-05		5.87E-08	1.68E-05			
102	cis-1,2-Dichloroethene		1.60E-02			2.84E+04							
103	Ethylbenzene	9.70E-02	3.90E+01	6.17E+04		2.84E+05	6.32E-04		3.42E-07	6.32E-04			
104	Methylene Chloride	2.60E-01	3.30E+00	1.83E+05		1.70E+05	1.80E-05		1.53E-06	1.95E-05			
105	Methyl-tert-butyl ether	6.00E-03	4.00E-03	1.84E+05			2.18E-08			2.18E-08			
106	Tetrachloroethene		5.00E-03	2.98E+04		2.84E+04	1.68E-07			1.68E-07			
107	Toluene	1.50E-01	2.10E+00	2.43E+04		5.68E+05	8.65E-05		2.64E-07	8.68E-05			
108	Trichloroethene		1.10E-02			1.70E+04							
109	Xylenes	1.70E-01	7.10E+01			5.68E+06			2.99E-08	2.99E-08			
110	Aniline		NA b)	4.12E+07	2.51E+04	1.99E+04							
111	Anthracene	4.40E+00	NA		1.08E+06	8.52E+05		4.092E-06	5.17E-06	9.26E-06			
112	Benzo(a)anthracene	6.50E+00	NA										
113	Benzo(b)fluoranthene		NA										
114	Benzo(k)fluoranthene		NA										
115	Benzo(a)pyrene		NA										
116	Benzo(g,h,i)perylene	3.70E-01	NA		1.08E+05	8.52E+04		3.441E-06	4.34E-06	7.79E-06			
117	Bis(2-ethylhexyl)phthalate	3.90E+00	NA		1.36E+04	5.68E+04		2.86E-04	6.87E-05	3.55E-04			
118	Chrysene	9.70E-01	NA										
119	Fluoranthene	5.80E-01	NA		1.43E+05	1.14E+05		4.045E-06	5.11E-06	9.15E-06			
120	Indeno(1,2,3-cd)pyrene	2.80E-01	NA										
121	2-Methylnaphthalene	2.30E+00	NA		7.17E+04	5.68E+04		3.208E-05	4.05E-05	7.26E-05			
122	Naphthalene	1.50E+00	NA	1.28E+08	7.17E+04	5.68E+04	1.17E-08	2.092E-05	2.64E-05	4.74E-05			
123	2-Nitroaniline		NA	8.09E+06	1.08E+03	8.52E+02							
124	3-Nitroaniline		NA		1.08E+03	8.52E+02							
125	4-Nitroaniline		NA		1.08E+04	8.52E+03							
126	n-Nitrosodiphenylamine	4.40E+00	NA										
127	Phenanthrene	1.80E+01	NA		1.08E+05	8.52E+04		1.67E-04	2.11E-04	3.79E-04			
128	Pyrene	6.50E+00	NA		1.08E+05	8.52E+04		6.045E-05	7.63E-05	1.37E-04			
129	Aroclor 1016		NA			1.99E+02							
130	Aroclor 1260	1.30E-01	NA										
131	4,4'-DDD	2.30E+01	NA										
132	4,4'-DDE	1.30E-01	NA										
133	4,4'-DDT	4.20E+01	NA		1.79E+03	1.42E+03		2.34E-02	2.96E-02	5.30E-02			
134	alpha-BHC	4.90E+01	NA										
135	beta-BHC	6.50E+00	NA										
136	delta-BHC	3.30E-02	NA										
137	gamma-BHC (Lindane)		NA		1.08E+03	8.52E+02							
138	gamma-Chlordane	2.80E-03	NA	2.84E+07	1.79E+03	1.42E+03	9.86E-11	1.562E-06	1.97E-06	3.54E-06			
139	Dieldrin		NA		1.79E+02	1.42E+02							
140	Endrin Aldehyde		NA		1.08E+03	8.52E+02							
141	Heptachlor Epoxide	1.80E-03	NA		4.66E+01	3.69E+01		3.863E-05	4.88E-05	8.74E-05			
142	Arsenic	2.10E+01	NA		1.08E+04	8.52E+02		1.95E-03	2.47E-02	2.66E-02			
143	Barium	2.60E+02	NA	1.99E+07	1.76E+05	1.99E+05	1.31E-05	1.48E-03	1.31E-03	2.80E-03			
144	Beryllium	2.30E+00	NA	8.09E+05	5.02E+02	5.68E+03	2.84E-06	4.58E-03	4.05E-04	4.99E-03			
145	Cadmium	5.00E+00	NA	8.09E+06	8.96E+02	2.84E+03	6.18E-07	5.58E-03	1.76E-03	7.34E-03			
146	Chromium (III)	3.70E+02	NA		6.99E+05	4.26E+06		5.29E-04	8.69E-05	6.16E-04			
147	Copper	2.70E+02	NA		1.43E+06	1.14E+05		1.88E-04	2.38E-03	2.57E-03			
148	Cyanide (total)		NA		7.17E+05	5.68E+04							
149	Lead	2.50E+02	NA										
150	Mercury	4.30E+00	NA	1.22E+07	7.53E+02	8.52E+02	3.52E-07	5.71E-03	5.05E-03	1.08E-02			
151	Nickel	5.40E+01	NA		2.87E+04	5.68E+04		1.88E-03	9.51E-04	2.83E-03			
152	Selenium	1.00E+01	NA		1.79E+05	1.42E+04		5.58E-05	7.05E-04	7.60E-04			
153	Silver	3.90E+00	NA		7.17E+03	1.42E+04		5.44E-04	2.75E-04	8.19E-04			
154	Zinc	7.60E+02	NA		2.15E+06	8.52E+05		3.53E-04	8.92E-04	1.25E-03			
155													
156								GRAND TOTAL		1.75E-01	Cumulative noncancer risk		
157	a) = Unsaturated subsurface soil data used. Saturated soil data not used.												
158	b) not applicable, as constituent does not meet Pennsylvania Act 2 definition of volatility												
159	c) lead target concentration is EPA's recommended lead concentration for residential soils.												

CONSTRUCTION WORKER EXPOSURE SCENARIO
SUNOCO MARCUS HOOK , PHILLIPS ISLAND

Risk-based reference concentrations were needed to evaluate exposure potential to a hypothetical construction worker assumed to be engaged in intrusive activities that would bring the worker in contact with residual constituents in soil. To evaluate this exposure scenario, the worker was assumed to be exposed by way of inhalation of volatile constituents emanating from the soil, by way of incidental ingestion of soil during the work day, and by way of dermal contact with soil.

The general algorithm for exposure of a construction worker was taken from the Texas Natural Resource Conservation Commission's (TNRCC's) petroleum storage tank program (TNRCC, 1997). It was assumed that a construction worker would be engaged in construction activities involving excavation for 5 days/week over a period of 12 weeks during a single year. For exposure to carcinogenic constituents, exposure dose received over the 12-week exposure period was apportioned over a 70-year lifetime. For noncarcinogenic constituents, exposure dose received over the 1-year exposure duration was used as the basis for the calculation of risk-based target concentrations. The worker was assumed to have 3,300 cm2 of exposed skin, which amounts of the head, forearms, and arms (TNRCC, 1997). The amount of soil adherence to exposed skin was assumed to be 0.12 mg/cm2 (TNRCC, 1997). There are no existing dermal absorption values for constituents in the soil medium; as an alternative, default values were obtained from the TNRCC's Texas Risk Reduction Program (TRRP; TNRCC, 1999). The amount of soil incidentally ingested by way of hand-to-mouth contact during a workday was assumed to be 480 mg/day (TNRCC, 1997; EPA, 1991a). For inhalation exposure, it was assumed that a 0.5 acre source area existed and that the construction worker would be exposed by inhalation of respirable-fraction dust and vapors of volatile constituents having a Henry's Law constant of at least 1E-05 atm-m3/mol or greater and a molecular weight of 200 g/mol or less (EPA, 1991b). Volatilization factors for individual volatile constituents and the particulate emission factor for a 0.5 acre source area (i.e., an area that is assumed to contain constituents in the soil) were calculated using the algorithms and default input parameters contained in EPA's Soil Screening Guidance (1996a, b). Chemical properties data were obtained from the Soil Screening Guidance (EPA, 1996a, b); missing values were taken from chemical properties tables included in the TNRCC's TRRP (TNRCC, 1999).

Toxicity data needed for calculation of risk-based target concentrations were obtained from EPA's Integrated Risk Information System (IRIS; EPA, 2000). Missing toxicity data were supplemented with data obtained from EPA's Health Effects Assessment Summary Tables (HEAST; EPA, 1995) and TNRCC's TRRP (TNRCC, 1999). Gastrointestinal absorption values needed for conversion of oral toxicity data to dermal toxicity data were obtained from the TNRCC's TRRP (TNRCC, 1999).

Risk-based target concentrations for constituents in soil are contained in accompanying spreadsheets. Note that for carcinogenic constituents, the reference concentrations

correspond to the lower of a one-in-one million cancer risk (i.e., 1E-06 cancer risk) or a hazard index of one. For noncarcinogenic constituents, the reference concentrations correspond to a hazard index of one.

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CONSTRUCTION WORKER SCENARIO
SUN MARCUS HOOK FACILITY
EXPOSURE BY WAY OF INGESTION, VAPOR/DUST INHALATION, AND DERMAL CONTACT WITH SOIL

$$C\ (mg/kg) = \frac{RL \times AT \times BW \times 365\ days/yr}{(((URF/RfC \times 1000ug/mg \times EF \times ED \times BW)/(VF + PEF)) + (SFd/RfD \times 10\text{-}6\ kg/mg \times EF \times ED \times SA \times AF \times ABS) + (SFo/RfD0 \times 10\text{-}6\ kg/mg \times EF \times ED \times IRs))}$$

Assumptions			VALUE	
C	=	concentration in soil, mg/kg	calculated	
RL	=	target cancer risk level	1.00E-05	
		target hazard index	1	
AT	=	averaging time for carcinogens, yr	70	
		averaging time for noncarcinogens (equals ED), yr	1	
BW	=	adult body weight, kg	70	
EF	=	exposure frequency for a construction worker, days/yr	60	5 events/week for 12 weeks TNRCC 1997
ED	=	exposure duration for a construction worker, yr	1	
SA	=	exposed skin surface area, cm2	3300	head + forearms + hands TNRCC 1997
AF	=	dermal soil adherence factor, unitless	0.12	TNRCC 1997
ABS	=	dermal absorption default value for volatile organic constituents	0	
		dermal absorption default value for semivolatile organic constituents	0.1	
		dermal absorption default value for inorganic constituents	0.01	
IRs	=	incidental soil ingestion rate for a construction worker, mg/day	480	EPA, 1991, TNRCC 1997
RfDo	=	oral reference dose, mg/kg-day	chem-specific	
RfC	=	reference concentration, mg/m3	chem-specific	
RfDd	=	dermal reference dose, mg/kg-day	chem-specific	
URF	=	unit risk factor, ug/m3	chem-specific	
SFd	=	dermal cancer slope factor, (mg/kg-d)-1	chem-specific	
SFo	=	oral cancer slope factor, (mg/kg-day)-1	chem-specific	
VF	=	volatilization factor (m3/kg), 1/2-acre exposure area	chem-specific	EPA, 1996.
PEF	=	particulate emission factor (m3/kg), 1/2-acre exposure area	1.32E+09	EPA, 1996

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Constituent	URF	RfC	CSFo	RfDo	GI Absorp	CSFd	RfDd	ABS	1/2-Acre VF	Cancer Inhalation (mg/kg)	Cancer Dermal (mg/kg)	Cancer Ingestion (mg/kg)	Cancer Cumulative (mg/kg)	Noncancer Inhalation (mg/kg)	Noncancer Dermal (mg/kg)	Noncancer Ingestion (mg/kg)	Noncancer Cumulative (mg/kg)
Acetone		5.90E-01		1.00E-01	NA		NA	0	1.43E+04		0			51274.28	0	88715.278	3.25E+04
Benzene	7.80E-06	6.00E-03	2.90E-02	3.00E-03	NA	NA	NA	0	3.11E+03	1698.962	0	21414.03	1.57E+03	113.58773	0	2661.4583	1.09E+02
2-Butanone (MEK)		1		0.6	NA		NA	0	16635		0			101194.97	0	532291.67	8.50E+04
Carbon Disulfide		0.7		0.1	NA		NA	0	1358		0			5782.8107	0	88715.278	5.43E+03
Chloroform	2.30E-05	0.097	0.0061	0.01	NA	NA	NA	0	3028	560.6176	0	101804.4	5.58E+02	1786.7682	0	8871.5278	1.49E+03
Ethylbenzene		1		0.1	NA		NA	0	6141		0			37357.576	0	88715.278	2.63E+04
Methylene Chloride	4.70E-07	3	0.0075	0.06	NA	NA	NA	0	2840	25731.15	0	82800.93	1.96E+04	51829.888	0	53229.167	2.63E+04
Toluene		0.4		0.2	NA		NA	0	4529		0			11020.529	0	177430.56	1.04E+04
Xylenes		0.43		2	NA		NA	0	6347		0			16602.614	0	1774305.6	1.64E+04
Anthracene				0.3	0.89		0.3	0.1							3226010.1	266145.83	2.46E+05
Benzo(a)anthracene	8.80E-05		0.73		0.89	0.73		0.1		63875000	10311.45	850.6944	7.86E+02				
Benzo(b)fluoranthene	8.80E-05		0.73		0.89	0.73		0.1		63875000	10311.45	850.6944	7.86E+02				
Benzo(k)fluoranthene	8.80E-06		0.073		0.89	0.073		0.1		6.39E+08	103114.5	8506.944	7.86E+03				
Benzo(a)pyrene	8.80E-04		7.3		0.89	7.3		0.1		6387500	1031.145	85.06944	7.86E+01				
Benzo(g,h,i)perylene				3.00E-02	0.89		3.00E-02	0.1							322601.01	26614.583	2.46E+04
Bis(2-ethylhexyl)phthalate			1.40E-02	2.00E-02	0.19	7.37E-02	3.80E-03	0.1			102157	44357.64	3.09E+04		40862.795	17743.056	1.24E+04
Chrysene	8.80E-07		0.0073		0.89	0.0073		0.1		6.39E+09	1031145	85069.44	7.86E+04				
Fluoranthene				0.04	0.89		0.04	0.1							430134.68	35486.111	3.28E+04
Indeno(1,2,3-cd)pyrene	8.80E-05		0.73		0.89	0.73		0.1		63875000	10311.45	850.6944	7.86E+02				
2-Methylnaphthalene				0.04	0.89		0.04	0.1							430134.68	35486.111	3.28E+04
Naphthalene		0.003		0.02	0.89		0.02	0.1						24090000	215067.34	17743.056	1.64E+04
n-Nitrosodiphenylamine			0.0049		0.25	0.0196		0.1			384048.8	126736.1	9.53E+04				
Phenanthrene				0.03	0.89		0.03	0.1							322601.01	26614.583	2.46E+04
Pyrene				0.03	0.89		0.03	0.1							322601.01	26614.583	2.46E+04
Aroclor 1016	5.70E-04		2		0.81	2		0.1		9861404	3763.678	310.5035	2.87E+02				
Aroclor 1260	5.70E-04		2		0.81	2		0.1		9861404	3763.678	310.5035	2.87E+02				
4,4'-DDD			0.24		0.7	0.24		0.1			31363.99	2587.529	2.39E+03				
4,4'-DDE			0.34		0.7	0.34		0.1			22139.29	1826.491	1.69E+03				
4,4'-DDT	9.70E-05		0.34	5.00E-04	0.7	0.34	5.00E-04	0.1		57948454	22139.29	1826.491	1.69E+03		5376.6835	443.57639	4.10E+02
alpha-BHC	1.80E-03		6.3		0.97	6.3		0.1		3122778	1194.819	98.57253	9.11E+01				
beta-BHC	5.30E-04		1.8		0.97	1.8		0.1		10605660	4181.865	345.0039	3.19E+02				
delta-BHC																	
gamma-BHC (Lindane)		5.00E-04	1.3	3.00E-04	0.97	1.3	3.00E-04	0.1			5790.275	477.6976	4.41E+02	4015000	3226.0101	266.14583	2.46E+02
gamma-Chlordane	1.00E-04	7.00E-04	0.35	5.00E-04	0.8	0.35	5.00E-04	0.1		56210000	21506.73	1774.306	1.64E+03	5621000	5376.6835	443.57639	4.10E+02
Dieldrin	4.60E-03		16	5.00E-05	0.5	16	5.00E-05	0.1		1221957	470.4598	38.81293	3.59E+01		537.66835	44.357639	4.10E+01
Endrin Aldehyde		1.00E-04		3.00E-04	0.5		3.00E-04	0.1						803000	3226.0101	266.14583	2.46E+02
Arsenic	4.30E-03		1.5	3.00E-04	0.95	1.5	3.00E-04	0.01		1307209	50182.38	414.0046	4.10E+02		32260.101	266.14583	2.64E+02
Barium		5.00E-04		7.00E-02	0.07		4.90E-03	0.01						4015000	526914.98	62100.694	5.48E+04
Beryllium	2.40E-03	2.00E-05		2.00E-03	0.007		1.40E-05	0.01		2342083			2.34E+06	160600	1505.4714	1774.3056	8.10E+02
Cadmium	1.80E-03	2.00E-04		1.00E-03	0.025		2.50E-05	0.01		3122778			3.12E+06	1606000	2688.3418	887.15278	6.67E+02
Chromium (III)		1.00E-04		1.5	0.013		1.95E-02	0.01						803000	2096906.6	1330729.2	4.04E+05
Copper		1.00E-03		0.04	0.57		0.04	0.01						8030000	4301346.8	35486.111	3.50E+04
Cyanide (total)		5.00E-03		0.02	0.5		0.02	0.01						40150000	2150673.4	17743.056	1.76E+04
Lead																	
Mercury		3.00E-04		3.00E-04	0.07		2.10E-05	0.01						2409000	2258.2071	266.14583	2.38E+02
Nickel	4.80E-04			0.02	0.04		8.00E-04	0.01		11710417			1.17E+07		86026.936	17743.056	1.47E+04
Selenium		2.00E-04		0.005	0.5		0.005	0.01						1606000	537668.35	4435.7639	4.39E+03
Silver		1.00E-05		0.005	0.04		2.00E-04	0.01						80300	21506.734	4435.7639	3.52E+03
Zinc				0.3	0.2		6.00E-02	0.01							6452020.2	266145.83	2.56E+05